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Global trading versus linking: Architectures for international emissions trading

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A B S T R A C T

International emissions trading is widely seen as an indispensable policy pillar of climate change mitigation [Stern, N., 2007. The Economics of Climate Change. The Stern Review. Cambridge University Press, New York]. This article analyzes five different types of trading architectures, classified into two top–down (UNFCCC driven) and three bottom–up (driven by individual countries or regions) approaches. The two types of approaches are characterized by a trade-off between environmental effectiveness and political feasibility, respectively, whereas their relative cost-effectiveness depends on implementation details. Bottom–up architectures constitute imperfect substitutes for top–down architectures in terms of environmental effectiveness, and thus remain mere fallback options. However, especially the 'formal linking' architecture can act as complement in terms of cost-effectiveness.

1. Introduction

The last years have witnessed a considerable amount of political activity geared towards the establishment of emissions trading systems. Amongst other things, this reflects the fact that emissions trading is generally seen as an indispensable pillar of climate change mitigation, and is expected to constitute a key building block of future international climate policy (e.g. Stern, 2007).

The Kyoto Protocol and the Marrakesh Accords established an inter-governmental trading system that is set to run for five years, from 2008 until the end of 2012. On this market, which covers the emissions of 37 states, representing 29% of the world's CO_2 emissions in 2004 (CAIT, 2008),[1] governments can trade emission permits—here called Assigned Amount Units (AAU)—which in principle allows to minimize the costs of compliance with their Kyoto reduction targets. They can also use credits generated under the Joint Implementation (JI) and Clean Development Mechanisms (CDM).

Even earlier, in 2005, the European Union launched its emission trading system (EU ETS), which regulates about 10,000 facilities that currently emit around 2 Gt of CO_2 per year (Skjaerseth and Wettestad, 2008). With a value of 50 bn US$ the EU ETS dominates the international carbon market, which totaled to 64 bn US$ in 2007 (Capoor and Ambrosi, 2008). EU policy-makers have emphasized that, irrespective of the outcome of the UNFCCC negotiations on a post-Kyoto climate policy package, the EU ETS will remain in place even after 2012 (EU Council, 2007).

Plans for the introduction of domestic emissions trading systems are also underway in several other Annex-I countries.[2] These regional activities are flanked by the recent establishment of the International Carbon Action Partnership (ICAP), a forum that was created with the explicit intention of exploring the "(…) potential linkage of regional carbon markets" (ICAP, 2007).

These developments can be understood as manifestations of two different approaches towards the establishment of emissions trading systems: first, there is the top-down approach, characterized by a centralized multilateral decision-making process and embodied in the UNFCCC negotiations. Second, there is the bottom-up approach, associated with decentralized decision-making of individual nations or sub-national entities that implement emissions trading systems uni-, bi- or plurilaterally (Zapfel and Vainio, 2002).

These processes yield two different types of institutional architectures for international emissions trading. The backbone of 'top-down' architectures is emissions trading between governments, while 'bottom-up' architectures rest upon the implementation and possible linkage of regional systems, based

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[1] Throughout our paper, data from CAIT (2008) refers to CO_2 emissions of the year 2004, excluding emissions from LULUCF.

[2] On the national level these include New Zealand, Australia, Switzerland, the United States, Canada, and Japan. Sub-national initiatives for emissions trading also exist in the US (the Regional Greenhouse Gas Initiative (RGGI), California, the Western Climate Initiative (WCI), and the Midwestern Greenhouse Gas Accord), Canada (some provinces are members to WCI), and Japan (Tokyo and Kyoto).

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on company-level emissions trading. This article aims to describe, analyze and compare these different institutional architectures.[3]

In the course of our analysis, we will argue that top-down and bottom-up architectures show characteristic differences in three key aspects. These are:

- environmental effectiveness
- cost-effectiveness
- political feasibility

Our main findings can be summarized as follows: because of their inclusiveness, top-down approaches tend to cover a larger share of global emissions and thus offer a higher degree of environmental effectiveness than bottom-up approaches. However, a significant share of global emissions could also be captured by means of a decentralized approach, in which a carbon market is created by linking existing domestic or regional ETS. The environmental effectiveness of both approaches can be enhanced by integrating baseline-and-credit schemes, e.g. the CDM of the Kyoto Protocol.

If emissions price equalization is the sole criterion, top-down approaches also fare better in terms of economic effectiveness. But if plausible market imperfections associated with emissions trade between governments (such as market power or information asymmetries) are taken into account, price equalization is unlikely to be a sufficient criterion for efficiency, which requires the equalization of marginal abatement costs. Bottom-up approaches, based on preexisting trading systems between companies, provide a more robust price signal, and can be very efficient once they are 'linked'.

High political feasibility emerges as the main strength of bottom-up approaches, and, at the same time, biggest hurdle for top-down architectures. For the latter, a full international agreement on burden-sharing constitutes a condition sine qua non, while the former lends itself to the formation of a coalition-of-the-willing with subsequent enlargements.

We conclude that the apparently intuitive view of bottom-up and top-down approaches as (imperfect) substitutes needs to be amended. In as much as bottom-up trading architectures bring about not the optimal, but the feasible, they remain a second-best alternative to a top-down global cap-and-trade system in terms of environmental effectiveness. However, when viewed as building blocks that allow putting a cost-effective and expandable carbon market into place without further delay, their supportive role in the eventual establishment of a global carbon market becomes apparent.

The remainder of our contribution is organized as follows: we begin in Section 2 by addressing questions of terminology and definition. Top-down architectures are described and analyzed in Section 3, bottom-up architectures are dealt with in Section 4. A comparative analysis and discussion are given in Section 5. We summarize our findings and present our conclusion in Section 6.

2. Definitions

Discussions about emission trading systems use a distinct lingo, drawing on a number of terms and concepts (e.g. offset credits) that are relatively new, and sometimes lack a clear definition. Hence, before introducing the conceptual framework for the analysis and comparison of different ETS architectures, we want to briefly clarify the basic terminology, as employed in this article.

Cap-and-trade systems set a binding, absolute cap on total emissions, but allow for certificates—corresponding to the right to emit a specific volume of emissions—to be traded among the covered entities, which are either nations or companies. The Kyoto Protocol trading system for Annex-B countries is an example for cap-and-trade at the governmental level, while the EU ETS operates at the company level. In contrast, baseline-and-credit systems define a certain baseline such as a business-as-usual projection or a relative target, and only allow emission reductions that go beyond this baseline to be used as sellable credits (often referred to as 'offsets'). In this study, we understand baseline-and-credit systems as non-binding systems, meaning that there is no penalty if the baseline is exceeded. The CDM and JI mechanisms established under the Kyoto Protocol are examples of such non-binding baseline-and-credit systems.

We use the terms carbon market and emissions trading system interchangeably to refer to both cap-and-trade and baseline-and-credit systems. The more general term emissions trading architecture is used to denote the overarching structure of relations between emissions trading systems that are implemented all over the world. Different emissions trading architectures can be compared with regard to their degree of integration or fragmentation.[4] Fragmentation means that there are several trading systems with none or only few linkages and, correspondingly, different prices for permits. Integration occurs if there is either only one global trading system or there are sufficient linkages between different carbon markets to lead to an equalization of permit prices across these systems.

In what follows, we interpret the ongoing political efforts in terms of two systematically different approaches, namely the 'top-down' and the 'bottom-up' approach to international emissions trading. In our comparative analysis, we will argue that the associated emissions trading architectures differ particularly in three aspects, which we set out beforehand.

Environmental effectiveness refers to the capability of an emissions trading architecture to bring about significant reductions in global emissions. Its potential for doing so depends, first of all, on the share of global emissions that are actually covered by the emissions trading regime. But taking that as given and assuming a certain emissions target is, however, not sufficient for evaluating its environmental effectiveness, because the offsetting effect of leakage is neglected.[5] Formally, the *percentage* reduction of global emissions can be expressed by the following equation:

$$\text{Global Reduction} = \text{Regime Reduction}\ x\ (\text{Regime Emissions}/\text{Global Emissions})\ x\ (1 - \text{Leakage Rate})$$

[3] 'Intermediate' architectures situated in between the basic cases of bottom-up and top-down are, of course, also conceivable, e.g. in the form of harmonized national policies (we thank the referee for pointing this out). However, since we focus on international emissions trading and the way it is implemented under different architectures, these cases are not treated here.

[4] In distinguishing integrated and fragmented architectures, we draw on Biermann et al. (2007) who define universalism–which corresponds to our notion of integration–as "(…) a situation in which all countries of relevance in a given issue area (a) are subject to the same regulatory framework; (b) participate in the same decision-making procedures (…); and (c) agree on a core set of common commitments." Fragmentation occurs if these conditions are violated.

[5] Leakage occurs if the regulation of emission intensive industries in one country leads to an expansion of those industries in other, less or unregulated countries, due to a shift in comparative advantage. The impact of this effect will depend on a number of factors, including the size of the carbon price differential, the trade exposure of affected sectors, and the relative importance of the expected persistence of the cost gap for investment decisions. International sectoral agreements, border tax adjustments and the free allocation of allowances (Neuhoff, 2008) have been proposed to address leakage concerns. In general, the available evidence suggests that this effect would not be a serious problem in most sectors, at least in the short- to mid-term (Stern, 2007; Neuhoff, 2008; The Economist, 2008).

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Because our study focuses on different approaches towards the establishing of a global carbon market, we deliberately abstain from a political economy discussion of how and at which level emissions targets are ultimately set. However, we realize that–considering the decisive role this parameter plays for the actual environmental effectiveness–for accuracy we should rather speak of the *potential* environmental effectiveness of a trading architecture.

Cost-effectiveness requires the minimization of the costs of achieving a given emissions reduction target. Conversely, cost-effectiveness also means that a given amount of abatement expenditure leads to the highest possible emission reduction. From a standard result of environmental economics it is well known that cost-effectiveness depends on the equalization of marginal abatement costs across all regions and sources (e.g. Tietenberg, 2003). In theory, market instruments such as permit trade or harmonized taxes ensure cost-effectiveness by associating a unique price with the 'bad' emissions, which, in equilibrium, corresponds to the marginal abatement costs. In practice, however, the emerging emissions price under a permit trading scheme may deviate from marginal abatement costs, in particular if (i) one or more actors possess market power,[6] (ii) regulators trade on behalf of firms but do not have full information on the abatement costs incurred by the latter (Kerr, 2000), and (iii) not all economic sectors are included in the scheme.

Finally, the question of *political feasibility* cannot be sensibly excluded from the discussion of any carbon market architecture, especially if it transcends the national domain. It is mainly related to requirements of participation and consensus, and to transaction costs. Evidently, in order to establish a highly integrated trading architecture, players need to agree on a common regulatory framework, and especially on a set of mutually acceptable emission caps. The latter generally have significant distributional implications, as allocations represent each player's cost-free endowment and thus largely determine the required effort. In consequence, bargaining over burden-sharing becomes a strategic game where self-interested players have an incentive to free-ride on the mitigation efforts of others by implementing targets with low stringency (Helm, 2003; Rehdanz and Tol, 2005). This turns the negotiation of regional emission budgets into the single-most important stumbling block in the creation of an inclusive international climate policy, and impedes high levels of participation in integrated trading structures.[7] Thus, we compare different architectures in view of their chance of successful implementation given these difficulties. In addition, trading architectures can be compared in terms of the transaction costs that arise from creating the necessary institutional structure for government- or company-level trading systems, or baseline-and-credit schemes. In this context, we assume that high transaction costs reduce political feasibility.

In the following two sections, we discuss five top-down and bottom-up architectures of international emissions trading. After outlining their principal features, we analyze their characteristics along the three dimensions just described.

[6] A case in point would be Russia's bargaining power with its large amounts of 'hot air' within the Kyoto trading framework. See also Böhringer and Löschel (2003).

[7] This is confirmed by studies in non-cooperative game theory that mostly come to rather pessimistic conclusions about the chances of full cooperation on the climate problem (see, e.g. Carraro and Siniscalco, 1992; Barrett, 1994). Limited cooperation in the form of 'climate coalitions' seems more likely to emerge, possibly facilitated by linking the cooperation to other issues such as research and development (Carraro and Siniscalco, 1997), or free-trade (Barrett, 1997).

3. Top-down architectures

We differentiate between two different types of top-down architectures: a 'global cap-and-trade' architecture, which serves as the benchmark for our analysis, and a 'Kyoto-II' architecture, which builds on the structure of the existing Kyoto trading system and could act as a starting point for a follow-up agreement.

3.1. Global cap-and-trade

A global cap-and-trade architecture implies that every country in the world adopts a well-defined and limited GHG emissions budget for its entire economy, and that emission allowances can be traded between governments (e.g. Vattenfall, 2006). As the sum of these national emission caps represents a definite upper bound on total global emissions (assuming compliance), the environmental effectiveness of this architecture would be maximal.

Theoretically, global-cap-and-trade can achieve cost-effectiveness, because a single price for emissions is established across all sectors and regions in the world. Integrated coverage of all world regions and sectors maximizes the gains from trading, as emissions are reduced in places where this can be achieved at the lowest possible costs.

However, given that a large share of all tradable allowances will very likely be concentrated in the hands of a rather small group of countries,[8] vesting them with considerable market power, permit trade between governments will arguably be characterized by strategic—i.e. price influencing—behavior. In fact, it seems questionable whether a single, world-wide price of carbon would emerge at all, given that many transactions can be expected to occur in an 'over-the-counter' fashion, i.e. on the basis of bilateral bargaining and without public disclosure of the price.[9] With such constraints on competition, efficiency losses become inevitable and a potentially sharp increase in total abatement costs is to be expected, as was shown, e.g., in simulations by Böhringer and Löschel (2003).

Moreover, even in a perfectly competitive inter-governmental permit market, information asymmetries between governments and companies would limit the former's knowledge about the true marginal abatement costs incurred by the latter. In particular, this would be the case if national emission targets are not implemented by means of a domestic emissions trading scheme (Hahn and Stavins, 1999). Thus, unless an appropriate price revealing mechanism is put into place, it will be difficult for governments to optimize their trading positions on the global carbon market (Kerr, 2000). Finally, even if governments had perfect knowledge about domestic abatement costs, one cannot assume them to act as pure cost-minimizers, as in the case of firms.[10]

Possibly the greatest hurdle to an implementation of a global cap-and-trade architecture consists in its prerequisite, i.e. an agreement on global burden-sharing. Not only have countries different views on the urgency and their responsibility for the climate problem (Ott et al., 2008), but there is also a constant risk of blockade by players with vested interests when negotiations for a comprehensive global trading system involves 192 voting parties.

[8] In 2004, the biggest five emitters, i.e. the US, China, Russia, Japan, and India accounted for 51% of global CO_2 emissions (Source: CAIT, 2008).

[9] See e.g. Point Carbon's, 2008 reporting on the confidentiality of the negotiations about trading Assigned Amount Units between Japan, Hungary and Czech Republic.

[10] We thank the referee for pointing this out.

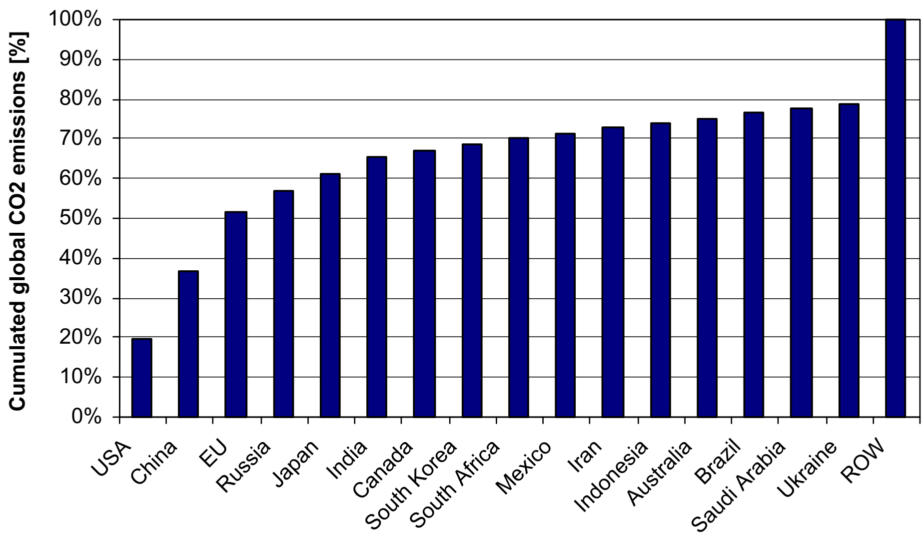

Fig. 1. Largest emitters' cumulative shares of global CO_2 emissions. Data for year 2004, excluding LULUCF. Source: CAIT (2008).

Another barrier to political feasibility are high transaction costs, as the reaching of global agreement on carbon market rules and the implementation of the corresponding national provisions such as monitoring, reporting and verification systems (MRV), as well as emission registries, constitutes a formidable challenge. The rules agreed upon—after long and painful negotiations—in the Marrakesh accords (Yamin and Depledge, 2004) as well as the experience and the regulatory framework developed in regional trading systems like the EU ETS could of course serve as a starting point. Still, their implementation would remain challenging, not only, but especially for least-developed countries (Victor, 2007).

On the whole, a global cap-and-trade architecture would promise high environmental effectiveness due to its universal emissions coverage. Cost-effectiveness, however, is likely to be compromised as long as emissions are traded by governments. Finally, large doubts remain with regard to its political feasibility, at least in the short term, given the high transaction costs and the need to achieve a global consensus on international burden-sharing.

3.2. Kyoto II: global trading with and without caps

Some of the difficulties of the global cap-and-trade scheme can be mitigated by implementing a global carbon market where only a limited group of countries—e.g. Annex-I countries—implements a cap-and-trade system while all other countries—e.g. developing countries—participate by means of 'trade without cap'. This architecture would closely resemble the Kyoto Protocol's framework, in which only Annex-B countries assume binding targets, while all others can host CDM baseline-and-credit projects. Given the critique of the CDM in its current form, e.g. with regard to additionality and transaction costs (Schneider, 2007; Michaelowa et al., 2003), various reform proposals for the baseline-and-credit system are currently discussed (UNFCCC, 2008). For instance, it would be conceivable to have a menu of schemes suiting different sectoral and regional conditions.

The environmental effectiveness of this architecture is a priori limited because of its incomplete emissions coverage. As shown in Fig. 1, the distribution of CO_2 emissions across countries implies that the climate problem is rather inapt to be solved by a limited size coalition-of-the willing: even though three big players (US, China, and EU) stand out, they still only account for 52% of all emissions.[11] In fact, if one wants to reach a 90% threshold of global emissions, already 48 countries are needed. In particular, any ambitious effort based on a partial cap-and-trade needs to include the currently second largest emitter, China, and thus cannot circumvent the difficult issue of burden-sharing vis-à-vis developing countries.[12]

Furthermore, the fact that developing countries and/or other countries are free to refrain from adopting binding emission targets opens the door to leakage. In principle, this is true even if all uncapped countries are integrated by means of non-binding baseline-and-credit systems. However, such schemes may be designed in such a way as to make sure that countries can only sell credits if their emissions stay below some predetermined level, e.g. below business-as-usual emissions (Philibert, 2000). Offering such incentives for emission control to uncapped parties, in particular developing countries, would enhance the environmental effectiveness of a Kyoto-II-type architecture.

Within the core group of cap-and-trade countries, this architecture has the same potential for cost-effectiveness and the same problems due to market imperfections as the global cap-and-trade system. However, in presence of baseline-and-credit mechanisms, the overall cost-effectiveness will depend on the specific design of the latter, e.g. whether there are restrictions on imported credits (such as in the Kyoto Protocol by means of a poorly defined 'supplementarity' provision), and on the incentives provided for uncapped regions. Ideally, baseline-and-credit systems introduce opportunity costs for emissions in uncapped countries, remain uncontroversial in terms of baseline definitions, and keep transaction costs at the minimum level. In reality, of course, there is no widely agreed upon and easily implementable approach to setting baselines (Baron and Ellis, 2006). Therefore, such mechanisms are likely to merely pave the way towards the eventual adoption of absolute caps, where concerns about environmental and cost-effectiveness would lose their relevance.

Regarding political feasibility, formal agreement on burden-sharing would only be required between cap-and-trade regions in this architecture, as other countries would not have to assume

[11] In this context, Barrett (2007) characterizes the global public good problem associated with climate change mitigation as an 'aggregate efforts' problem: the provision of the public good depends on the *combined* efforts of all states.

[12] As a whole, the group of Annex-I countries represent 49.2% of global CO_2 emissions (CAIT, 2008).

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binding targets. However, in view of the past reluctance of a key emitter like the United States to accept a binding target, this hurdle nevertheless seems high.[13] Also, setting the necessary baselines for the baseline-and-credit mechanisms cannot be done without considering distributional aspects, since baselines determine the amount of credits that can be generated and sold into the capped market. Less stringent baselines increase the volume of profitable credit sales—but also the risk of 'hot air'—while they are reduced by more stringent baselines (Philibert, 2000).

Compared to the global cap-and-trade architecture, transaction costs are lower, because only capped countries need to establish the full institutional infrastructure required in cap-and-trade systems. Annex-I countries, for instance, have already implemented MRV and registry infrastructure in order to comply with the Kyoto Protocol. Still, there may be need for revision, and the institutional requirements for some baseline-and-credit systems under discussion may be substantial (Baron and Ellis, 2006).

To sum up, a Kyoto-II-type architecture only approximates a global cap-and-trade one, and thus can at best come very close to the latter's environmental and (potential) cost-effectiveness. However, the fact that it includes the option for developing countries to participate without having to accept binding emissions caps, and thereby to contribute to emission reductions, significantly enhances political feasibility. Still, reaching a full, detailed agreement, in particular with regard to burden-sharing and the parameters of the baseline-and-credit mechanism, would constitute a considerable political challenge.

4. Bottom-up architectures

We distinguish three bottom-up architectures with a gradually increasing degree of integration. First, 'fragmented markets' serves as the benchmark case characterized by a complete absence of intentional linkage of regional markets. Second, in the 'indirect linking' architecture carbon markets are linked indirectly as they accept credits from the same baseline-and-credit systems. Finally, 'formal linking' refers to fully integrated regional cap-and-trade systems in which all certificates are mutually recognized.

4.1. Fragmented markets

In the presence of two or more independent cap-and-trade systems that are installed at the national, supra- or sub-national level, and that do not have any intentional linkages between them, we speak of 'fragmented markets'. Even though international trade in goods already induces a certain tendency towards permit price convergence across different emissions trading systems,[14] prices will in general vary and thus prevent a cost-effective outcome. The degree of inefficiency increases—ceteris paribus—in proportion to the price differential between carbon markets.

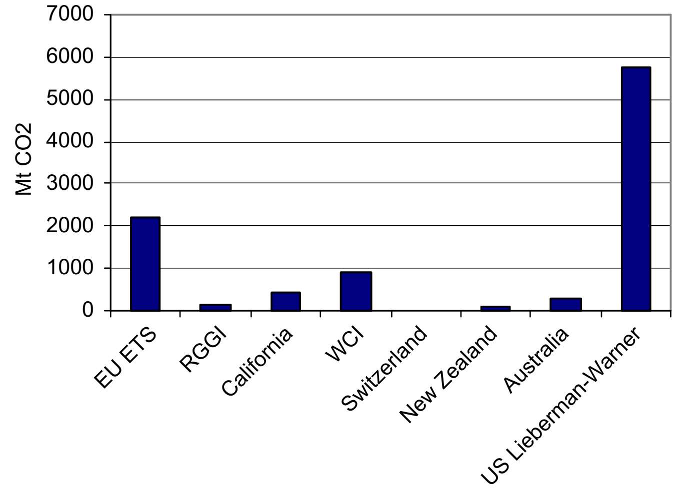

Fig. 2. Sizes of emerging regional carbon markets. Taken together (counting US regional and federal systems only once), they account for 27% of all global CO_2 emissions in 2004. Sources: Capoor and Ambrosi (2008), RGGI (2008), California Market Advisory Committee (2007), WCI (2007), FOEN (2008), New Zealand Ministry for the Environment (2007), Australia Prime Ministerial Task Group on Emissions Trading (2007), CAIT (2008).

Based on current expectations, fragmented markets would encompass only a small share of global emissions (see Fig. 2), implying that any reduction efforts would be particularly vulnerable to emission leakage. Moreover, without any coordinated measures taken by the independent ETSs there will be a very limited scope for baseline-and-credit schemes in developing countries, since demand for such credits would come from at most one of the independent trading systems (otherwise it would be the case of 'indirect linkage', discussed next). Hence, unless a large number of countries chooses to implement autarkic domestic cap-and-trade systems in the mid- to long-term, environmental effectiveness will remain low.

Since they operate independently, fragmented markets cannot ensure the equalization of permit prices and marginal abatement costs and, in consequence, fall short—possibly by a very large margin—of being cost-effective. Moreover, smaller systems may additionally suffer from efficiency losses if large domestic players with market power are present (e.g. very large utility companies).

Being close to a world of laisser-faire, fragmented markets require no cooperation and thus there is no need for an international agreement on burden-sharing. Transaction costs are the lowest among all carbon market scenarios, since the only requirement consists of the implementation of domestic systems in some industrialized countries, without any need for coordination and harmonization with other systems.

Recapitulating, the fragmented market architecture represents a politically highly feasible option due to very low transaction costs and no obligation for an international agreement. However, environmental and especially cost-effectiveness are both low.

4.2. Indirect linking

If at least two regional cap-and-trade systems accept credits from the same baseline-and-credit scheme, an indirect link

[13] Even though the prospects of US participation might have increased with the advent of the Obama presidency in 2009, one should keep in mind that any international treaty needs to be confirmed by a two thirds majority in the US Senate.

[14] In a trade-theoretic analysis, Copeland and Taylor (2005) argue that a cost-effective outcome (i.e. equalization of permit prices) can be reached even in absence of permit trade between carbon markets, due to the effects of trade in goods on the prices of non-traded inputs. However, their results are derived within a stylized theoretical model and based on strong assumptions, e.g. identical technologies and tastes across all countries, which are—at best—idealizations of the real world. This means that their results should for practical purposes be interpreted in the sense that 'international trade in goods induces a *certain tendency* towards equalization of the permit price'. That this is indeed plausible can be understood by a simple look at trade in fossil fuels: assume two identical countries with equal emission caps and a common domestic permit price. Now one country adopts a more stringent cap. As a consequence, its domestic permit price rises, and its consumption of fossil fuels must drop (neglecting CCS). In as much as that prompts the world market price of fossil fuels to fall, the opportunity

(*footnote continued*)
costs of not using fossil fuels in the second country rise, and so does its domestic permit price.

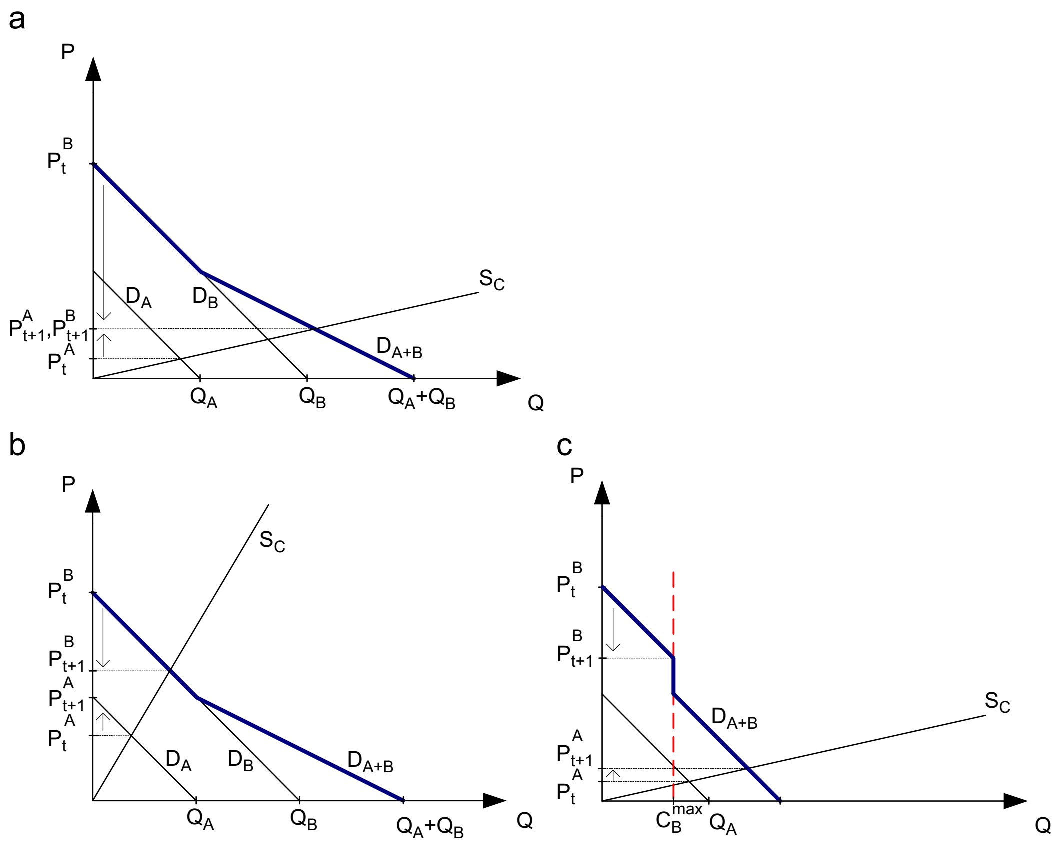

Fig. 3. Price convergence when cap-and-trade systems are linked indirectly via credits. D_A and D_B are credit demand curves for systems A and B, and D_{A+B} is the aggregate demand curve. S_C is the supply curve for credits. Q_A and Q_B are reduction amounts (BAU emissions minus cap) in systems A and B. The price level in system A prior to system B's joining of the credit market is P_t^A. The autarky price in system B without any linkage is P_t^B. The price levels in A and B after the entry of B into the credit market are P_{t+1}^A and P_{t+1}^B, respectively. In fig. (c), C_B^{max} is the import limit for credits in system B. The arrows indicate the direction of price changes resulting from indirect linking.

between them is established (Egenhofer, 2007). Depending on the supply curve for credits, cap levels, marginal abatement cost (MAC) curves, and quantity limits on the import of credits, indirect linking will lead to a complete or incomplete convergence of the allowance price in indirectly-linked cap-and-trade markets. Fig. 3a–c identifies the underlying mechanics for three cases.

For each case, we compare two periods. In the first period t, only cap-and-trade system A accepts credits from the baseline-and-credit scheme C, while cap-and-trade system B operates in autarky. In period t+1, system B also allows the import of permits from the baseline-and-credit scheme C, thereby establishing an indirect link between systems A and B. The cap-and-trade systems are assumed to have identical MAC curves (the slope of D_A and D_B is identical), but system A has a less ambitious cap than system B ($Q_A < Q_B$).

Fig. 3a illustrates the case of complete price convergence due to the indirect link. The price in system A increases from P_t^A to the new equilibrium price P_{t+1}^A ($=P_{t+1}^B$), while the price level in B decreases from P_t^B to P_{t+1}^B ($=P_{t+1}^A$).

In Fig. 3b, price convergence is incomplete because of the steep credit supply curve S_C. When entering the market for credits, system B buys credits at a market clearing price P_{t+1}^B which exceeds the maximal willingness to pay of system A. The latter then resorts to domestic abatement only, leading to a new and different internal allowance price P_{t+1}^A. Here, indirect linking brings about partial price convergence as the allowance price level in A increases, while it decreases in B.

Finally, in Fig. 3c price convergence also remains incomplete, this time because system B has adopted an import limit C_B^{max} on credits. In t+1 system B exhausts its import quota and purchases $\overline{0C_B^{max}}$ credits at the credit price of P_{t+1}^A. However, the domestic equilibrium allowance price in B nevertheless settles at the higher price P_{t+1}^B. Again, even though prices in A and B are not fully equalized, some price convergence occurs due to the indirect linking.

Therefore, a carbon market architecture with indirect linkages between regional trading systems will improve cost-effectiveness vis-à-vis the fragmented market case. By how much depends on the level of price convergence across systems, which, in turn, was shown to largely depend on the flatness of the credit supply curve. Therefore, a baseline-and-credit scheme that clears the way for large-scale investment opportunities into abatement, e.g. in the power sector, would be conducive to cost-effectiveness. In addition, company-level trading helps to ensure that true marginal abatement costs are revealed, while at the same time reducing concerns about market power, since—relative to top-down and fragmented architectures—a higher number of market participants are present.

As in the preceding case, environmental effectiveness depends on the extension of trading systems across regions, the scope for leakage, and the specific design features of baseline-and-credit schemes. Theoretically, the architecture with indirect links can affect a larger share of global emissions than fragmented markets, since the combined demand from different cap-and-trade schemes increases the scope for a larger-scale implementation of baseline-and-credit schemes. Nevertheless, on the whole one can expect environmental effectiveness to be lower than for top-down architectures, at least in the short- to mid-term, where only few domestic trading systems will emerge.

Like 'fragmented markets', the indirect linkages architecture requires only limited commitment to international cooperation.

The establishment of commonly accepted baseline-and-credit schemes in third countries (likely developing countries) is the one requirement that raises transaction costs relative to the latter architecture. However, concerns might arise in some countries that a 'flood' of low-price credits would lead to a deterioration of the domestic permit price. Although this would imply significant cost-savings in the short-run, it might be inconsistent with long-term objectives such as the transformation of the energy system or the achievement of an ambitious climate target.

In sum, a bottom-up architecture with indirect linkages improves cost-effectiveness relative to the previous case of fragmented markets. This holds to a lesser extent for environmental effectiveness. Both can be expected to remain below the level promised by top-down architectures. There are no significant barriers in terms of political feasibility.

4.3. Formal linking

Formal linking occurs whenever two (or more) regional emissions trading systems mutually recognize each others' allowances, i.e. they accept emission certificates issued in other systems as valid for compliance within their own system. A formal linking architecture is thus established through a concerted linking-decision of different regional trading systems (Tangen and Hasselknippe, 2005; Victor, 2007; Edenhofer et al., 2007).[15] Evidently, an immediate consequence of linking is the formation of a common emissions price.[16]

The benefit of enhanced cost-effectiveness comes, however, at the cost of contagiousness: once two emissions trading systems are linked, changes in the design or regulatory features in one system also influence the price formation in the other system.[17] For instance, if only one country decides to adopt a price ceiling in the form of a so-called safety valve,[18] then the entire linked market is in effect capped at the same price. Thus, there is a partial loss of control for domestic regulators over their own system, necessitating a high degree of coordination—and mutual trust—in the management of the joint carbon market. Relevant design issues with implications for the whole linked carbon market include, inter alia[19]

- the setting and modification of emission caps
- upper and lower ceilings for permit prices
- links to baseline-and-credit schemes, e.g. CDM
- banking and borrowing provisions
- compatible registries
- rules for monitoring, reporting and verification of emissions
- penalties and enforcement of compliance

To address these issues, institutional provisions in the form of linking agreements and joint regulatory bodies are required, both before and during the linking operation (Flachsland et al., 2008). In fact, as a first step in that direction, several countries and regions with existing or emerging regional cap-and-trade systems and with an openly expressed interest in linking have already joined forces and established the International Carbon Action Partnership (ICAP) in 2007. As one of its tasks, ICAP is to assess barriers to linking and work out solutions where such impediments may exist (ICAP, 2007).

Nevertheless, even if formal linking should become the preferred road for developing the international carbon market, there are three reasons why a concrete realization before 2013 seems very unlikely (see Fig. 4 for a timeline of emerging regional systems). First, most systems are still in the process of establishing their own domestic institutions, while the EU ETS is for the time being occupied with its own internal expansion and harmonization process. Second, linking partners will very likely want to first observe test phases of new trading systems in order to appraise their performance (e.g. Delbeke in ECCP, 2007). Third, strategic decisions on the future shape of international climate policy are not expected to emerge before the UNFCCC's Conference of Parties in Copenhagen 2009, suggesting that until then regions will generally be reluctant to commit to anything substantial.

Due to the limited coverage (regional and sectoral) that goes along with this bottom-up approach, its environmental effectiveness will be similarly limited as that of the indirect linkage architecture. For instance, the linked carbon markets of those emerging systems that are currently supporting the ICAP initiative and have at least proposed first drafts for a domestic ETS would correspond to about 3.6 Gt CO_2eq annual emissions, representing 12% of total global CO_2 emissions in 2004.[20] Leakage concerns are eliminated between linking partners, but persist with respect to uncapped third regions.

As already indicated, a carbon market architecture characterized by bottom-up linking of regional systems will lead to full price equalization across all involved systems, thereby enhancing the cost-effectiveness of the overall effort (Anger, 2008). An expanded and quasi-unified permit market also means more liquidity and efficiency, as large-scale trading at the company level but eliminates information asymmetry and market power problems.

Somewhat different from the other bottom-up architectures, formal linking can face problems in achieving high levels of participation because linked cap-and-trade systems need to agree on burden-sharing to some extent. This may seem surprising at first, since linking involves the coupling of presumably already capped trading systems. However, one can argue that a country with a relatively high domestic emissions price would be reluctant to link its permit market to that of another country with a relatively low emissions price, in as much as that would entail massive imports—and corresponding financial flows—of emission permits.[21] Also, regions with ambitious overall climate policy targets will use linking and the implicit efficiency gains as a bargaining chip in climate policy negotiations, which will make them reluctant to link to systems with low stringency. Linking to a low-price permit market could also undermine a country's efforts to spur technological innovation via high permit prices (Neuhoff, 2008). So, even though a link in such circumstances would allow both countries to lower their short-term abatement costs by trading emission permits, it may not be a desirable option for reasons of political economy and long-term strategic climate policy considerations (Flachsland et al., 2008).

[15] We only consider bilateral linkages. A unilateral link is established if cap-and-trade system A accepts allowances from another system B for compliance, but not vice-versa. In such a system, the allowance price in A would remain at or below the price level of B. See e.g. Jaffe and Stavins (2008).

[16] The permit price might differ by a constant factor if systems use different measurement units, e.g. metric and short tons. The latter unit is in fact envisaged for RGGI.

[17] Depending on the level of price convergence, this will also be the case in the indirect linking case.

[18] A safety valve indicates a provision under which the regulator issues additional emission permits if a certain maximum permit price is reached. See e.g. Jacoby and Ellerman (2004).

[19] These issues are treated in-depth by, e.g., Flachsland et al (2008), IEA (2005), Jaffe and Stavins (2007).

[20] Calculation based on the sources indicated in Fig. 2.

[21] In fact, linking faces an immanent free-riding problem, as there is an incentive to relax caps in order to generate additional revenue from exporting allowances (Helm 2003; Rehdanz and Tol 2005).

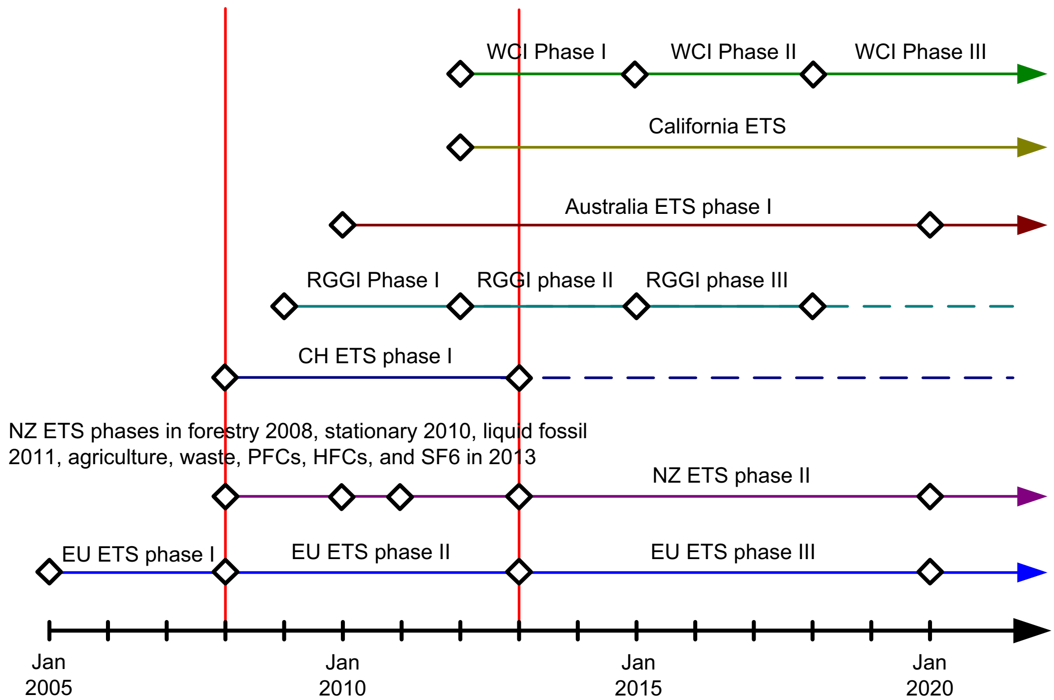

Fig. 4. Timeline for emerging emissions trading systems (ETS). The two vertical lines indicate the time span of the Kyoto Protocol's first commitment period.

The linking of regional trading systems incurs some transaction costs, as several design features of trading systems may need to be harmonized prior to linking.[22] This might constitute a decisive disadvantage in comparison to indirect linking, as stressed by Jaffe and Stavins (2008). These costs can, however, be contained if emerging systems incorporate the prerequisites for linking already during their design phase, thereby circumventing the need for costly ex-post changes of already implemented systems. Given that, and taking into account the lower number of negotiation partners, we conclude that formal linking should incur lower transaction costs than top-down approaches.

Overall, the formal linking architecture promises high cost-effectiveness. Being similar to the indirect linking case, environmental effectiveness remains lower than under a full global trading system, at least in the short- to mid-term. Political feasibility becomes more problematic compared to the other bottom-up approaches, since linking markets need to mutually accept each others' reduction efforts and implied range of permit prices. Transaction costs will be higher than for the other bottom-up architectures, but lower than under top-down approaches.

5. Discussion

Table 1 summarizes the key characteristics of the five carbon market architectures under investigation. It illustrates how the choice between integrated top-down and fragmented bottom-up architectures corresponds to a trade-off between high environmental effectiveness on the one hand, and political feasibility on the other. The picture is less clear-cut for cost-effectiveness.

Concerning environmental effectiveness, a top-down architecture with global-cap-and-trade obviously offers the best possibility for significant cuts in global emissions. On the other end of the spectrum, a bottom-up architecture consisting of fragmented markets is unlikely to significantly curb global emissions. The situation is less definite for the other, 'intermediate' architectures: with a sufficient number of committed participants, the indirect linking and especially the formal linking approach may come close to the environmental effectiveness of a Kyoto-II architecture. In fact, while a bottom-up approach may be more likely to start out with lower initial emissions coverage, it can expand step-by-step, thereby gradually increasing the share of global emissions that it covers.

Both the Kyoto-II and all of the bottom-up schemes have to face the challenge of controlling emissions leakage; as with Kyoto II, the formal and indirect linking architectures can be extended to provide economic incentives for emission control to third countries in the form of appropriately designed baseline-and-credit mechanisms. Finally, short-term concerns leakage can be mitigated if most or all of those countries that are close trade competitors participate in the linked carbon market.[23]

Among participating countries, top-down architectures always allow for a complete equalization of the permit price. But concerns over market power distortions and doubts about the proper revelation of domestic marginal abatement costs reduce the cost-effectiveness prospects of these architectures. By contrast, bottom-up approaches lead to permit price equalization only in the formal linking case or—under the condition that the credit supply curve is sufficiently flat and no restrictions are imposed on credit imports—in the indirect linking case. However, the price signal may be more robust, since company-level trading systems are better suited to resolve the information asymmetry between governments and companies and are less prone to market power distortions.

In terms of political feasibility top-down approaches resemble 'all-or-nothing' options: without international consensus on burden-sharing, complete political standstill is imminent. This constitutes a very tangible threat, given that any kind of

[22] These issues are treated in-depth by, e.g., Flachsland et al (2008), IEA (2005), Jaffe and Stavins (2007).

[23] We neglect the options of compensation schemes and border tax adjustments (see Neuhoff, 2008).

Table 1
Comparison of the five carbon market architectures[a].

	Integrated global trading	Kyoto II	Formal linking	Indirect linkages	Fragmented systems
Environmental effectiveness					
Coverage	++	+ depends on CDM design	o (+) depends on participation	o (+) depends on participation	− depends on participation
Prevention of leakage	++	+	o	−	−−
Cost-effectiveness					
Price convergence	++	++	++	+	−
Overcoming MAC information asymmetry	o	o	++	++	++
Limiting market concentration	−	−	++	+	o
Political feasibility					
Ease of achieving agreement on cooperation	−−	−	+	++	++
Low transaction costs	−−	−	o	+	++

The ratings, from very high (++) to neutral (o) to very low (−−) represent a relative measure of differences between the architectures.
[a] Note that the ratings for environmental effectiveness of the three scenarios 'Kyoto II', 'formal' and 'indirect linking' crucially depend on the level of participation (number and size of systems) and the design of baseline and credit schemes. Ratings should thus be interpreted as sort of "average" assessments.

agreement can rather easily be blocked by countries with vested interests. Similarly, agreement on the design details of the trading and accounting system will be more difficult to achieve than for bottom-up approaches with fewer participants. In fact, the latter will always enable cooperating regions to jointly reduce emissions in a cost-effective manner, even in absence of a global accord on burden-sharing and regulatory design.

Finally, transaction costs of top-down architectures are relatively high, because a larger number of players need to implement the institutional infrastructure required to participate in the common carbon market. Albeit to a lesser extent, direct linking also incurs significant costs, since it may require extensive regulatory harmonization, which possibly justifies a preference for indirect linking in the short-run (Jaffe and Stavins 2008).

On longer time horizons, the main issue in a comparison between top-down and bottom-up architectures must be the climate target that they are able to support. Game theoretical considerations of international agreements typically suggest a dichotomy of 'narrow and deep' versus 'broad and shallow', that is, agreements with fewer members can achieve higher levels of cooperation than those with many members (Downs et al., 1998). Intuitively, such a pattern can be expected whenever the level of cooperation and ambition embodied in an agreement corresponds to a lowest common denominator outcome. Such reasoning seems to be applicable in the realm of climate change, where the 'shallowness' of the Kyoto Protocol fits well into the scheme.[24]

However, due to the global public good nature of climate change, which manifests itself through concerns about free-riding and leakage, a coalition of few or several like-minded countries is unlikely to implement the deep emission cuts that would fit into the 'narrow and deep' picture. Therefore, the current situation can better be characterized in terms of a dichotomy of 'broad and shallow' versus 'narrow and shallow': unless global agreement on an ambitious long-term target, burden-sharing, and institutional design is achieved, a broad (i.e. top-down) agreement will reflect the lowest common denominator interest of all parties. Likewise, within narrow (bottom-up) approaches, countries' reduction efforts cannot be expected to significantly exceed those occurring in a situation without any cooperation, due to concerns over leakage and free-riding.

In view of an ambitious long-term climate objective, such as the European Union's target to limit global warming to 2 °C above pre-industrial levels (EU Council, 2007), only two scenarios remain viable: either the international community decides to cooperate and agrees on global targets, burden-sharing and a regulative system to implement a 'broad and deep' climate policy in top-down mode; or it embraces a bottom-up approach, initially 'narrow and shallow', but with a successively broadening participation and deepening commitment. Such an increase in participation, in fact, does not seem implausible once the key uncertainties of the climate change problem (e.g. technologies, costs, and climate damages) are reduced and the feasibility of carbon trading is demonstrated by a group of frontrunners. This process, however, would need to proceed quickly in order to generate emission reductions in line with low-stabilization scenarios suggested by the IPCC (2007).

Hence, if ambitious climate policy targets require swift emission reductions, top-down architectures appear quasi indispensable. Moreover, their major weakness—low political feasibility due to the need to resolve the burden-sharing issue—can in a way be understood as a strength: the very crux of the climate problem is addressed at once, which keeps up the pressure on negotiators, and prevents procrastination up to a point in time where low stabilization becomes unfeasible. Thus, within this long-term point of view, bottom-up architectures appear as imperfect substitutes of top-down approaches, serving as fallback option if a global agreement cannot be achieved right away. Consequently, they would mainly serve to bring new momentum to the currently stagnant efforts to establish a global, integrated system.

On the other side, the two approaches can be viewed as complementary in the sense that bottom-up architectures may serve as essential building blocks for more comprehensive top-down architectures. This way, efficient regional carbon markets can already be put into place, while the delicate question of burden-sharing is deferred for some time. For example, it would be conceivable that after the Kyoto Protocol's expiry in 2012 a group of countries willing to adopt binding economy-wide caps

[24] The targets of the Kyoto Protocol—without counting the US—correspond to a reduction of global emissions by about 5% with respect to the business-as-usual emissions in 2010, as expected in 1997. Source: own calculation based on EIA (1997).

proceeds with the protocol's inter-governmental cap-and-trade system, and formally link their emerging domestic trading systems within this overarching structure. By devolving inter-governmental permit trading to the company level the economic performance of the international carbon market would be improved.[25] But unlike the Kyoto scheme, this architecture can be designed as an open system, where countries can join by linking up their domestic ETS whenever they feel ready, or whenever the political momentum in the country has reached a sufficient level.[26] Such an approach could be environmentally and economically more effective than pure bottom-up approaches, while being less prone to political deadlock than the top-down approach.

6. Conclusions

A comprehensive global system represents the benchmark for any future international emissions trading architecture, at least in terms of effective climate protection and access to low-cost abatement opportunities. However, given the considerable political challenge posed by top-down approaches—well reflected in the current multilateral climate policy negotiations—they suffer from the risk of a political deadlock of indeterminate duration.

On the other hand, the bottom-up road to international emissions trading is constantly challenged by the question of whether emission reductions in this context can have a significant environmental impact at all. Still, this institutional approach may better suit the current state of politics, and therefore could help to bring about not the ideal but at least the feasible. Also, permit trade among companies is preferable to permit trade among governments on efficiency grounds, since distortions due to high market concentration are avoided and the liquidity and transparency of the emerging emissions market are reinforced. By linking up with countries that have similar export profiles, leakage concerns can be mitigated at least partially. Suitably designed, bottom-up approaches enable a gradual integration of initially fragmented trading architectures, resulting in increasing environmental and cost-effectiveness. They allow countries to join whenever they feel ready, or whenever the political momentum in the country reaches a sufficient level.

If top-down and bottom-up approaches are seen as complements rather than substitutes, following both tracks in parallel via UNFCCC and ICAP appears to be a robust strategy, especially in view of the current uncertainty surrounding the multilateral climate policy negotiations. In case of a break-down of the latter, bottom-up linking of regional trading systems stands ready as a fallback option and alternative to the continuation of the Kyoto trading system. In any case, integrated trading architectures imply considerable challenges to international coordination, particularly regarding joint regulation. Therefore, exploring governance options for carbon market regulation in multilateral architectures should be a key objective for further research on international emissions trading.

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[25] This approach is represented by the EU ETS, where transactions of allowances across country borders are mirrored by transfers of AAUs between national Kyoto registries.

[26] As it was the case with Australia and the Kyoto Protocol (Keohane and Raustiala, 2008).

References

Anger, N., 2008. Emissions trading beyond Europe: linking schemes in a post-Kyoto world. Energy Economics 30, 2028–2049.

Australia Prime Ministerial Task Group on Emissions Trading, 2007. Report of the task group on emissions trading.

Baron, R., Ellis, J., 2006. Sectoral crediting mechanisms for greenhouse gas mitigation: institutional and operational issues. OECD/IEA. Available at: 〈http://www.iea.org/textbase/papers/2006/greenhouse.pdf〉.

Barrett, S., 1994. Self-enforcing international environmental agreements. Oxford Economic Papers 46, 878–894.

Barrett, S., 1997. The strategy of trade sanctions in international environmental agreements. Resource and Energy Economics 19, 345–361.

Barrett, S., 2007. Why Cooperate? The Incentive to Supply Global Public Goods. Oxford University Press, Oxford.

Biermann, F., Pattberg, P., van Asselt, H., Zelli, F., 2007. Fragmentation of global governance architectures. The case of climate policy. Global governance working Paper, no. 34, December 2007.

Böhringer, C., Löschel, A., 2003. Market power and hot air in international emissions trading: the impacts of US withdrawal from the Kyoto protocol. Applied Economics 35 (6), 651–663.

CAIT, 2008. CAIT (Climate Analysis Indicators Tool) database of the World Resource Institute. Accessed in August 2008. 〈http://cait.wri.org/〉.

California Market Advisory Committee, 2007. Recommendations for designing a greenhouse cap-and-trade system for California. Recommendations of the market advisory committee to the California air resources board. June 30, 2007. Available at: 〈http://www.climatechange.ca.gov/events/2007-06-12_mac_meeting/2007-06-01_MAC_DRAFT_REPORT.PDF〉.

Capoor, K., Ambrosi, P., 2008. State and Trends Of The Carbon Market 2008. The World Bank, Washington D.C., May 2008. Available at: 〈http://siteresources.worldbank.org/NEWS/Resources/State&Trendsformatted06May10pm.pdf〉.

Carraro, C., Siniscalco, D., 1992. The International dimension of environmental policy. European Economic Review 36, 379–387.

Carraro, C., Siniscalco, D., 1997. R&D cooperation and the stability of international environmental agreements. In: Carraro, C. (Ed.), International Environmental Agreements: Strategic Policy Issues. Edward Edgar, Cheltenham.

Copeland, B.R., Taylor, M.S., 2005. Free trade and Global warming: a trade theory view of the Kyoto Protocol. Journal of Environmental Economics and Management 49 (2), 205–234.

Downs, G.W., Rocke, D.M., Barsoom, P.N., 1998. Managing the evolution of multilateralism. International Organization 52 (2), 397–419.

ECCP (European Climate Change Programme), 2007. Final Report of the 4th meeting of the ECCP working group on emissions trading on the review of the EU ETS on Linking with emissions trading schemes of third countries. 14–15 June 2007. Available at: 〈http://ec.europa.eu/environment/climat/emission/pdf/070614_15finalreport.pdf〉.

Edenhofer O., Flachsland, C., Marschinski, R., 2007. Towards a global CO_2 market. Expertise for the Policy Planning Staff in the Federal Foreign Office. Potsdam Institute for Climate Impact Research, May 2007. Available at: 〈http://www.pik-potsdam.de/members/flachs/publikationen/towards-a-global-co2-market〉.

Egenhofer, C., 2007. The making of the EU emissions trading scheme: status, prospect and implications for business. European Management Journal 25 (6), 453–463.

EIA (Energy Information Administration), 1997. International Energy Outlook. US Department of Energy, Washington, DC.

EU Council, 2007. Brussels European Council 8/9 March 2007. Presidency Conclusions. 7224/1/07 REV 1.

Flachsland, C., Edenhofer, O., Jakob, M., Steckel, J., 2008. Developing the International Carbon Market. Linking Options for the EU ETS. Report to the Policy Planning Staff in the Federal Foreign Office. Available at: 〈http://www.pik-potsdam.de/members/edenh/publications-1/carbon-market-08〉.

FOEN, Swiss Federal Office for the Enviroment, 2008. Startschuss zum Emissionshandel in der Schweiz. Press Release (in German), 11.06.2008. Available at: 〈http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=de&msg-id=19266〉.

Hahn, R.W., Stavins, R.N., 1999. What Has the Kyoto Protocol Wrought? The Real Architecture of International Tradable Permit Markets. AEI Studies on Global Environmental Policy, The AEI Press, Washington, D.C.

Helm, C., 2003. International emissions trading with endogenous allowance choices. Journal of Public Economics 87, 2737–2747.

ICAP (International Carbon Action Partnership), 2007. Political Declaration. Lisbon, 29 October 2007. Available at: 〈http://www.icapcarbonaction.com/docs/icap_declaration.pdf〉.

IEA (International Energy Agency), 2005. Act Locally, Trade Globally. Emissions Trading for Climate Policy, IEA/OECD, Paris.

IPCC (Intergovernmental for Climate Change), 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Jacoby, H.D., Ellerman, D., 2004. The safety valve and climate policy. Energy Policy 32, 481–491.

Jaffe, J., Stavins, R.N., 2007. Linking Tradable Permit Systems for Greenhouse Gas Emissions: Opportunities, Implications and Challenges. Prepared for: International Emissions Trading Association. November 2007. Available at: 〈http://belfercenter.ksg.harvard.edu/files/IETA_Linking_Report.pdf〉.

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Jaffe, J., Stavins, R.N., 2008. Linkage of Tradable Permit Systems in International Climate Policy Architecture. Discussion Paper 2008–07, Cambridge, Mass.: Harvard Project on International Climate Agreements, September 2008.

Keohane, R., Raustiala, K., 2008. Toward a Post-Kyoto Climate Change Architecture: a Political Analysis. The Harvard Project on International Climate Agreements, July 2008, Discussion Paper 08-01. Available at: 〈http://belfercenter.ksg.harvard.edu/files/Keohane%20and%20Raustiala%20HPICA1.pdf〉.

Kerr, S., 2000. Domestic greenhouse gas regulation and international emissions trading. In: Kerr, S. (Ed.), Global Emissions Trading. Key Issues for Industrialized Countries. Edward Elgar Publishing, Cheltenham UK.

Michaelowa, A., Stronzik, M., Eckermann, F., Hunt, A., 2003. Transaction costs of the Kyoto mechanisms. Climate Policy 3, 261–278.

Neuhoff, K., 2008. Tackling Carbon. How to Price Carbon for Climate Policy. University of Cambridge Electricity Policy Research Group, 23.05.2008. Available at: 〈http://www.climate-strategies.org/uploads/Tackling_Carbon_final_230508.pdf〉.

New Zealand Ministry for the Environment, 2007. The Framework for a New Zealand Emissions Trading Scheme.

Ott, H., Sterk, W., Watanabe, R., 2008. The Bali roadmap: new horizons for global climate policy. Climate Policy 8 (1), 91–95.

Philibert, C., 2000. How could emissions trading benefit developing countries? Energy Policy 28, 947–956.

Point Carbon, 2008. 'Hungary sees rush of AAU buyers.' Published: 26 March 2008; and 'Japan eyes Czech carbon credit deal.' Published: 19 August 2008.

Rehdanz, K., Tol, R., 2005. Unilateral regulation of bilateral trade in greenhouse gas emission permits. Ecological Economics 54, 397–416.

RGGI, 2008. Retrieved from 〈http://www.rggi.org〉, in May 2008

Schneider, L., 2007. Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement. Öko-Institut, Report prepared for WWF. Available at: 〈http://www.oeko.de/oekodoc/622/2007-162-en.pdf〉.

Skjaerseth, J.B., Wettestad, J., 2008. EU Emissions Trading. Initiation, Decision-Making and Implementation. Ashgate, Alderford.

Stern, N., 2007. The Economics of Climate Change. The Stern Review. Cambridge University Press, New York.

Tangen, K., Hasselknippe, H., 2005. Converging markets. International Environmental Agreements: Politics, Law and Economics 5 (1), 47–64.

The Economist, 2008. Emissions suspicions. Are countries that regulate greenhouse gases exposing their industries to unfair competition from those that do not? The Economist print edition, June 19th 2008.

Tietenberg, T., 2003. Environmental and Natural Resource Economics, sixth ed. Addison Wesley, Boston.

UNFCCC, 2008. Analysis of possible means to reach emission reduction targets and of relevant methodological issues. Technical Paper. FCCC/TP/2008/2, 6 August 2008. Available at: 〈http://unfccc.int/resource/docs/2008/tp/02.pdf〉.

Vattenfall, 2006. Curbing Climate Change. An outline of a framework leading to a low-carbon emitting society. Vattenfall AB, Stockholm, Sweden. Available at: 〈http://www.vattenfall.com/www/ccc/ccc/Gemeinsame_Inhalte/DOCUMENT/360168vatt/386246envi/P02.pdf〉.

Victor, D., 2007. Fragmented carbon markets and reluctant nations: implications for the design of effective architectures. In: Aldy, J.E., Stavins, R. (Eds.), Architectures for Agreement. Addressing Global Climate Change in the Post-Kyoto World. Cambridge University Press, New York.

WCI (Western Climate Initiative), 2007. Western Climate Initiative Statement of Regional Goal. Available at: 〈http://www.westernclimateinitiative.org/ewebeditpro/items/O104F13006.pdf〉.

Yamin, F., Depledge, J., 2004. The International Climate Change Regime. A guide to Rules, Institutions and Procedures. Cambridge University Press, New York.

Zapfel, P., Vainio, M., 2002. Pathways to European Greenhouse Gas Emissions Trading. History and Misconceptions. FEEM Working Paper no. 85.2002. Available at: 〈http://papers.ssrn.com/sol3/papers.cfm?abstract_id=342924〉.